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# SYSTEMATIC SURVEY ON BLOCKCHAIN INTEGRATION TO INFORMATION MANAGEMENT SYSTEMS - TRENDS, ISSUES AND PERSPECTIVES

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**Abstract**

The contemporary times have witnessed an exponential growth and prominence of blockchain, with many researchers terming this innovation as a universal technology having practical applications in almost every aspect of human life. In its short life it has been vividly explored that how this technology could leave a lasting impression on number of industries. The undertaken survey is an attempt to unfold a comprehensive and a systematic review that answers the question of how the blockchain could be utilized as a service for various applications within present days information systems. This survey also provides the reader with a deeper and more intuitive view on how this technology is helpful in securing and managing today's information system. It includes several examples of blockchain applications and studies put forward by various members of research community and their contribution in different scenarios. Moreover, it has been established that contemporary cloud- and edge-computing and structure of blockchain are paramount in sanctioning general adaption of blockchain as a technology for novel actors in today's world market.

**Keywords:** Blockchain, Information systems, decentralization, smart contracts,

## INTRODUCTION

Blockchain is one of the most sought-after research areas in contemporary times. Researchers have argued that this technology has manyfold applications across multiple disciplines such as Internet of Things [1], health care and medicine [2], intelligent transportation [2], banking, industries, information management systems and so on [3]. Blockchain; because of its architecture which enables enhanced security levels and its structure which makes it nearly impossible to create fraudulent activities, has potential to be practically extended to several other domains as well. Although blockchain based applications and tools may vary with respect to their implementation and purpose across different domains yet, the underlining general backbone structure for such blockchain based applications and tools would remain same [4]. In the simplest terms blockchain can be understood as a distributed ledger. Various distributed algorithms and hashing functions are used to make the tamper proof transactions. Though, it is possible to look the historical transactions however, it is impossible to make any alterations into those transactions of the Ledger because of distributed nature of blockchain [5].

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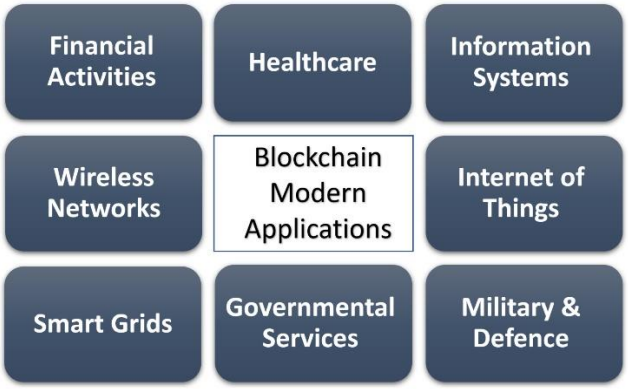


Figure 1. Various domains of blockchain application[6]

Generally, blockchain ledger is organized in peer-to-peer style. Therefore, a change in a single historical transaction would require a change in almost all the ledgers of the blockchain. Adding to that, this modification of ledger should also be accompanied by the proof of work concept which is a solid bedrock against overriding the ledger's history by high power processing machines. Proof of work is a method of including new transactions to the blockchain. Simply put it is generating a long string of characters [7] which matches the target hash for the current block [8]. Not only that but blockchain has also developed a potential for reliability and security for many information systems as well.

It was in early 2000s that the newly established idea of blockchain emerged that advocated distribution of a series of records in a substantial class of recipients who would behave as a promptly available source for establishing accuracy and integrity of individual records. However, it took some time for blockchain to be recognized as an emerging technology as initially there were no developed utilities based on blockchain at that time. It was only in 2009 that blockchain was revolutionized through the publication of "Bitcoin: a peer-to-peer electronic cash system"[9]. For the first time, the author introduced the idea of digital currency that does not went beyond the digital world and was founded on blockchain architecture.

In general terms, blockchain architecture eliminates the need for third parties for making a transaction and a transaction via blockchain could be ensured on small level. These transactions improve the information trails in the relevant information systems. This may hold potential for more in-depth analytics and market space responses. This idea is echoed in a useful way by the idea of smart contracts. Since these methods and ideas are generally applicable to any technology-related field, a thorough examination of blockchain applications is a laborious and constantly evolving task.

**SCOPE OF RESEARCH:**

Primarily, the undertaken research considers research works in the application domains of blockchain primarily in information systems. This systematic survey put an effort to record the blockchain instances, usage and impacts on various existing information systems. However, in achieving so, the work also summarizes the modern and practical applications of blockchain on various other domains. A very brief summary of a few of related works has been produced in a below table.

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Table 1. Summary of blockchain application domains

| Research Area | Contribution | Year |
|---|---|---|
| Energy Systems[10] | The work considers the implementation of blockchain in smart girds while keeping in mind the issues such as cyber security as well as energy data protection in smart grids. The authors have gone to provide solutions to various major security problems that big data and block chain can resolve. | 2022 |
| IoT[7] | Elaborates the importance and implementation of blockchain in IoT systems. Moreover, authors, based on important factors propose blockchain taxonomy for IoT. | 2022 |
| Supply chain management[11] | Authors have concluded that for SCM and logistics and other multi-organizational businesses blockchain is feasible option. Moreover, IoT-blockchain integration, asset tracking and smart contracts have huge potential in future. | 2022 |
| Transportation Systems[12] | The objective of this research is to provide an improved transportation system with minimized road accidents, less traffic congestion and a transport network that is free from the fraudulent messages and activities. Concept of smart coins has been incorporated in this research work the benefit those vehicles with the high rating messages. | 2022 |
| Industry 4.0[13] | the author argues that the amalgam of IoT technologies and blockchain is contributing towards robust distributed applications such as smart finance, smart manufacturing, smart supply chain management, smart cities, smart government and so on. The research also tackles the idea of incorporating artificial intelligence and 5G to handle the challenges connected with digital transformation in Industry 4.0. | 2022 |
| | | |

## PREVAILING SURVEYS

The usefulness and practicality of blockchain in the domain of information systems has been individually researched in many prevalent industries. The implementation of blockchain architectures has been suggested for reducing the overhead costs such as finances, time, and effort. However, we find the dearth of systematic literature review for the blockchain based information systems with one exception[4]. The rest of the literature that is available regards to specific views such as health industry, blockchain for smart cities, Internet of Things and so on.

## INFORMATION SYSTEMS

Broadly speaking, an information system is basically the combination of hardware, software as well as human beings. The hardware includes storage media, communication channels whereas the software includes the digital applications, communication protocols and standards. Such systems are not stand-alone business models. One can visualize information system as a triangle – people, processes, and computers - making three constituent elements of information system triangle. An information system needs to make sure all its constituent elements to be working properly to ensure its success. Therefore, for the successful implementation of any information system integration with the data and business process is critical. The focus of research studies in information systems has been to explore the various ways that ensure the successful implementation of such systems so that all concerned parties can get the relevant information effectively.

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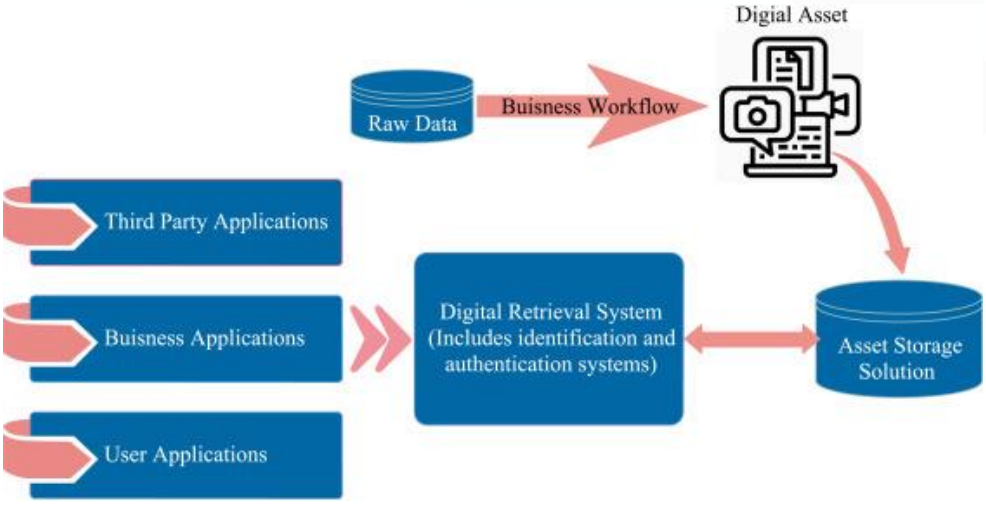


Figure 2. A generic form of information system depicting business logic, information storage, and data retrieval[4]

Information systems could be extended to multiple subject areas with varying practical applications. GIS (Geographic Information System) for instance is about collection, storage, and organization of geographical data that may include data such as longitude and latitude as well as street system and more. Similarly, healthcare information system may be utilized for safely communicating sensitive information about patients to relevant parties while at the same time developing protocols for authentication and identification to correctly identify pertinent parties [14]. In this regard Wu et al. [15] proposes sharing of patient's record with different parties in a decentralized way while using blockchain and at the same time making sure data integrity and data safety.

**BLOCKCHAIN FOR INFORMATION SYSTEMS**

Institutions such as governments and businesses that uphold and work with information systems may occasionally or regularly depend on certain technologies or the agents from third parties to complete certain jobs or sometimes sensitive information is to be communicated therefore, it is necessary that there should be an element of trust among all the involved parties. Blockchain has the capacity to establish a secure communication channel that ensures the safe integration of third-party products [16] while at the same time making sure not to release unnecessary information to third parties. Moreover, Lafourcade et al.[17] advocates the principle of interoperability so to enhance blockchain acceptance by all the involved parties. Interoperability facilitates interaction through integrated networks and blockchain transaction ledgers to ensure validity of all relevant parties.

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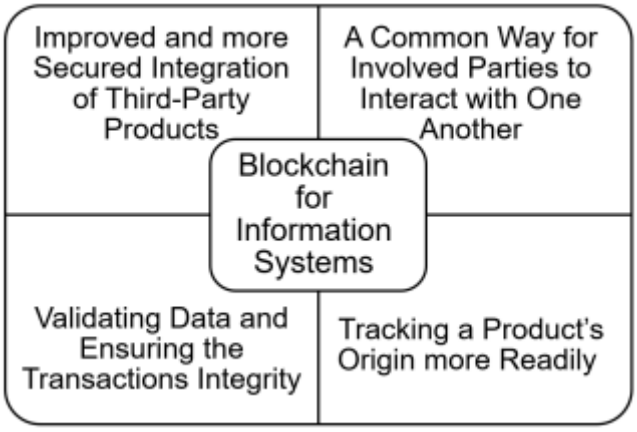


Figure 3. Various domains of blockchain application[6]

Blockchain, due to its decentralized nature has capacity for guaranteeing the transaction integrity and validating data. For this purpose concept of smart cards [18] has been put forward. The smart contract is basically ensuring that the agreement to which the two parties have arrived should be in form of coding using blockchain. It controls execution and exchanges made are completely trackable and reversable. Not only this but the blockchain could also be used to decide any disputes that may arise by conforming genuineness of digital signatures in a safe and decentralized way.

The amalgam of blockchain, information systems and supply chain could be extended to many businesses for numerous applications [19]. For instance, product provenance is considered by many businesses as a critical issue. The blockchain could assist in tracking the product's origin with more precision. A product can officially be confirmed at any given time and transactions cannot be altered so that end use of that product could be deceived [20].

## CHALLENGES AND PERSPECTIVES FOR ADOPTIG BLOCKCHAIN FOR INFORMATION SYSTEMS

Now we will outline some of the challenges that blockchain based information system face.

### 1.1 Minimizing the impact of third parties:

There are certain situations where organization and businesses may meet third parties to accomplish a particular task. In these circumstances it is necessary that an environment of trust must exist for the safe execution of a particular task. In such scenarios, blockchain could be used so reduce the impact of third-party items, applications, or agents as this technology provides a safe method of integration with the third-party products and tools while at the same time ensuring that sensitive information is not leaked to those parties.

As a test case, the adoption of the blockchain could benefit several institutions such as health care. There are instances where a third-party provider could request access to the patient's data and via some checks and balances placed in the system such requests are granted or denied. In the case of blockchain, a transaction request is attached to blockchain network that also contain past transactions which are

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related to the medical professionals or doctors and their corresponding patients. As it stands out that integrity, confidentiality, and availability all are noticed throughout this process [21]. It must be, however, pointed out that though, there are number of benefits of this technology in several industries including health care systems yet, some underlining requirements such as functionality and reliability must also be guaranteed. Moreover, decentralization and authentication, which are also the backbone of the blockchain technology, should be made integral part of health care information systems. In other words, within the system that implements the blockchain, transitory data should have some sort of security. Above principles are the most basic security concerns that are important to almost any industry [22].

Toufaily et al.[23] has highlighted the advantages and disadvantages of blockchain in various industries. The authors are also of the point of view that because of limited knowledge of the blockchain many organizations and industries are reluctant for the implementation of blockchain. Similarly, Otoum et al. [24] has added few more key concerns such as, security of data, anonymity of users, and intrusion detection and storage of data.

A three-layer architecture has been suggested as one of the key base components for blockchain based system. The first layer consists of cloud/web with a public API access. The next layer is a cloud middleware which interacts with smart contract APIs and HTTP servers. And the third and final layer is a blockchain network layer which is laced with the fundamentals provided through this technology [25].

Presently, health care industry and information system are witnessing a rise of blockchain system-based implementations. the use of this technology ranges from granular access control to accessing the health records and sharing the data. in a nutshell, through the basic principles of the blockchain such as security healthcare information system could get benefit.

### 1.2 Enhancing Interoperability

Similarly, interoperability also promotes the adoption and implementation of blockchain by supporting the common protocols of communication which are based on integrated networks and blockchain transaction ledgers and guarantee the authenticity of concerned members. The association of interoperability and blockchain can be detailed via three foundational interoperability – Structural, foundational, and semantic. The foundational interoperability suggests that communication should occur without interpreting data. Whereas structural interoperability comes up with schema and a way to implement it. And Symantec interoperability interprets the semantical data [26]. It is these concepts of interoperability that provides the essence of what and what not blockchain should deliver from a decentralized perspective. Decentralized applications have used these standards to significantly reduce interoperability. Any application that implements such a concept must adhere to fundamental principles, including patient-centeredness, structural interoperability, Turing completeness etc. [26].

Presently we witness a wide range of diverse systems that implement different protocols for interaction in the healthcare industry. Consequently, there is a challenge of interoperability to communicate on a shared communication protocol. The practical implementation of blockchain could provide a way to

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overcome this challenge by providing a common standard protocol by which different systems could be integrated in a single communication channel with one another, minimizing overhead and the health industries information systems [27]. The simple way forward is to utilize indexes for transactions or records of patients for reducing overhead via blockchain. Moreover, the end user would also be capable of generating his or her own sole digital signature. Not only this but Linn et al. [28] advocates certification validation through a which healthcare ledger could be appended or read by the end user in a more secure way.

### 1.3 Increasing efficiency

Before blockchain to be considered a minimally viable product in the healthcare industry, it must pass several tests. The implementation should ideally be intuitive, cost effective, and improve inter-system communication. Modern proposals expressly state that all these metrics of incentive are to be provided. Vora et al., [29] suggests system that prioritizes maintenance and storage effectiveness. The approach incorporates a realistic deployment of secure health records using blockchain technology and develops full nodes, archive nodes and light nodes to address storage overload issue. A comparable piece of work is Halloush et al., [30] who suggest a system that would be capable of settling intellectual property conflicts. The suggested system would make it possible to track the authenticity and provenance of intellectual property. These essential technological ideas come together to guarantee access control, user-friendliness, improved interoperability, and reliability. Obviously, there are other extra benefits that could potentially result from blockchain deployment. Consequently, user has additional control [31]. A healthcare blockchain application's end user can implement and exercise extra access control, but they can also anticipate more privacy and dependability for their respective healthcare information system stream. Moreover, end users could also anticipate good decisions by other involved parties as they have now greater access to the information.

### 1.4 Fault Tolerance and Compatibility issues:

Although blockchain's decentralized structure is something unique and promises an increased level of stability and security yet, the capacity of blockchain to suitably handle data of large scale is yet to be proven. Moreover, when it comes to security, the decentralized architecture is advantageous because it has some built-in security features as any change must be updated throughout the entire record. This makes it impossible for any fraud or forgery to take place without being quickly noticed. And this is also what makes blockchain a completely different approach then classical client server model.

The horizon of blockchain applications keep on expanding along with IOT also [32]. The contemporary implementation of IoT is for data centralization - that is keeping data at a single place. However, this approach could cause outages or data loss as servers may go offline or become inaccessible due to any reason. In this scenario the blockchain could help distributing data across the multiple points reducing the risk of information loss or inaccessibility.

The blockchain technology, however, is also prone to certain limitations. It's decentralized architecture is what that makes it different but also at the same time makes it vulnerable as technology of distributed

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ledger is somewhat limited and narrow in its extendibility towards larger systems [33]. Similarly, two different systems with different hardware resources could find each other with incompatible ledgers and if such systems are unable to detect this issue, then transactions may be halted or cancelled altogether.

Adding to that, problems could also occur due to communication among ledger participants. Computing resources relating to time occur in coincidence with space. There are numerous applications that may require a particular response within a given time slot especially the financial applications for a financial transaction require this as a security provision. In these circumstances, where disparate machines running these tools and have distinct processors and other hardware equipment, implementation of blockchain technology could become challenging [34]. Moreover, different type of data that is to be stored could also hinder the implementation of blockchain. For instance, lidar scans could take numerous gigabytes of data to be stored and this could cause problems to occur. The contemporary research is keen to make improvements on consensus protocols required for maintaining stability among each instance of a central ledger [35]. Implementing consensus protocol could reduce these types of issues. Li et al., [36] advocates Crux as an enhanced fault tolerance algorithm for implementing blockchain. Similarly, Muzammal et al.,[37] have concluded that distributed database working alongside or within could also cause some improvement in communication as well as response time between decentralized parties in the blockchain network. These databases could also putback components of a ledger in the case of a disaster that may cause loss of network components.

### 1.5 Expanding utilization off Blockchain

Some authors have also suggested amalgamating blockchain based applications with cryptographic techniques so to provide wider adoption of blockchain technologies and to secure an additional layer of safety and security [38]. Yogesh et al., [39] have come up with the suggestion for meeting UN's SDG's (Sustainability Development goals) via the adoption of blockchain. Moreover, Zeng et al., [40] have implemented blockchain for a park maintenance. There are also number of studies that suggest the extension of the blockchain technologies to several compartments of everyday life such as, for improving school's record management [41]. Observing fast moving trains to avoid fabricating collected data by sensors[42]. Similarly, this technology could also bring innovation and improvement in the construction of smart cities [43].

Needless to say, that there are variety of opportunities where blockchain technology could be employed. Blockchain's capacity to solve issue of fault tolerance via distinct network of software and hardware resources and distributed ledger makes it a strong candidate for its implementation in diverse situations and in a novel and fruitful way. However, while making progress with blockchain it is pertinent to be wise and cautious as there are also chances for mistakes. This technology's fault tolerance could be in certain situations and for certain businesses prove dangerous.

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### 1.6 Validation of data

The decentralized structure of blockchain makes it a viable tool for maintaining the integrity of transactions and validation of data. Presently, the methods for achieving this are not decentralized but they depend upon the trusted third-party tools. So how to then make sure that a third party is trustworthy? It is in these scenarios that blockchain comes into the picture and provides a viable means for ensuring the integrity and validation of data. One approach via blockchain could verify transaction integrity is to use "smart contracts" which could verify that the content of a digital contract is indeed digitally signed by the involved parties. Blockchain could also be used to dissolve any disputes and ensure the validity of signatures in a decentralized and safe manner[44].

Moreover, ensuring the validity and integrity is even more important in certain business dealing and functions of governments such as electoral process [45]. Awalu et al.,[46] suggest a blockchain based system for the e voting that depending on size of electoral could be scale down and scaled up. Moreover, the authors also suggest the way to ensure the authenticity of a voter by checking the digital signature of vote.

### 1.7 Maintaining data integrity

Maintaining the data integrity is also one of the proposed uses of blockchain. Liu et al., [47] puts forward blockchain as a source of the security, integrity, and privacy of data collected for the scientific studies.

## FINDINGS

It would take some time to realize the full potential of blockchain. Although several practical applications of blockchain have been explored but still, there are many situations where the deployment of the blockchain could be extended. In this connection developing open-source libraries and tools for blockchain that are commonly accessible to all would make it possible for small industries to integrate blockchain into their system without being trapped into edge or cloud computing environment available commercially. This could also create avenues for further expansion of blockchain technology on a larger scale. Also, the byproduct of such an exercise would lead to a greater public confidence and comprehension of blockchain ultimately leading towards a self-sustaining growth cycle and future goal of blockchain based tools, application, and software around the world.

## ANALYSIS AND CONCLUDING REMARKS

The overall study in to the available blockchain literature provides a glimpse towards various advantages, challenges, and perspectives of this technology for different industries.

It has become crystal clear that integrating blockchain could result in minimizing third parties enhancing interoperability as well as increasing efficiency. As a test case we studied health information systems where, due to several precautions, safety standards, and involvement of bureaucracy serious communication hurdles exist. It was concluded that enhanced interoperability and reduced third party involvement would result in a greater access control and providing end user and other different parties

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that are involved, with increased ability to have access to information which previously was a restricted zone. The other byproduct of this is reduced duplicity. Moreover, with an easier access to system, availability of real time data could be utilized to make better informed decisions. Delay in the data communication could also be reduced.

**REFERENCES**

1. Frikha, T., et al., Implementation of blockchain consensus algorithm on embedded architecture. Security and Communication Networks, 2021. 2021.
2. Zaabar, B., et al., HealthBlock: A secure blockchain-based healthcare data management system. Computer Networks, 2021. 200: p. 108500.
3. Chen, Q., et al., An incentive-aware blockchain-based solution for internet of fake media things. Information Processing & Management, 2020. 57(6): p. 102370.
4. Berdik, D., et al., A survey on blockchain for information systems management and security. Information Processing & Management, 2021. 58(1): p. 102397.
5. Fanning, K. and D.P. Centers, Blockchain and its coming impact on financial services. Journal of Corporate Accounting & Finance, 2016. 27(5): p. 53-57.
6. Krichen, M., et al., Blockchain for Modern Applications: A Survey. Sensors, 2022. 22(14): p. 5274.
7. Abdelmaboud, A., et al., Blockchain for IoT Applications: Taxonomy, Platforms, Recent Advances, Challenges and Future Research Directions. Electronics, 2022. 11(4): p. 630.
8. Kiayias, A. and D. Zindros. Proof-of-work sidechains. in International Conference on Financial Cryptography and Data Security. 2019. Springer.
9. Nakamoto, S., Bitcoin: A peer-to-peer electronic cash system. Decentralized Business Review, 2008: p. 21260.
10. Hasan, M.K., et al., Blockchain technology on smart grid, energy trading, and big data: security issues, challenges, and recommendations. Wireless Communications and Mobile Computing, 2022. 2022.
11. Raja Santhi, A. and P. Muthuswamy, Influence of blockchain technology in manufacturing supply chain and logistics. Logistics, 2022. 6(1): p. 15.
12. Vishwakarma, L. and D. Das, SmartCoin: A novel incentive mechanism for vehicles in intelligent transportation system based on consortium blockchain. Vehicular Communications, 2022. 33: p. 100429.
13. Chen, Y., et al., Applications of blockchain in industry 4.0: A review. Information Systems Frontiers, 2022: p. 1-15.
14. Lu, Q. and X. Xu, Adaptable blockchain-based systems: A case study for product traceability. Ieee Software, 2017. 34(6): p. 21-27.
15. Wu, H., et al. A patient-centric interoperable framework for health information exchange via blockchain. in Proceedings of the 2019 2nd International Conference on Blockchain Technology and Applications. 2019.

**ISSN:** 2776-1010 Volume 3, Issue 9, Sep., 2022

16. Mut-Puigserver, M., M.A. Cabot-Nadal, and M.M. Payeras-Capellà, Removing the trusted third party in a confidential multiparty registered eDelivery protocol using blockchain. IEEE Access, 2020. 8: p. 106855-106871.
17. Lafourcade, P. and M. Lombard-Platet, About blockchain interoperability. Information Processing Letters, 2020. 161: p. 105976.
18. Singh, A., et al., Blockchain smart contracts formalization: Approaches and challenges to address vulnerabilities. Computers & Security, 2020. 88: p. 101654.
19. Saberi, S., et al., Blockchain technology and its relationships to sustainable supply chain management. International Journal of Production Research, 2019. 57(7): p. 2117-2135.
20. Francisco, K. and D. Swanson, The supply chain has no clothes: Technology adoption of blockchain for supply chain transparency. Logistics, 2018. 2(1): p. 2.
21. Guo, R., et al., Secure attribute-based signature scheme with multiple authorities for blockchain in electronic health records systems. IEEE access, 2018. 6: p. 11676-11686.
22. Dwivedi, A.D., et al., A decentralized privacy-preserving healthcare blockchain for IoT. Sensors, 2019. 19(2): p. 326.
23. Toufaily, E., T. Zalan, and S.B. Dhaou. From start-ups to governments: challenges and opportunities of blockchain adoption in the MENA ecosystem. in Proceedings of the Second International Conference on Data Science, E-Learning and Information Systems. 2019.
24. Otoum, S., B. Kantarci, and H. Mouftah, A comparative study of ai-based intrusion detection techniques in critical infrastructures. ACM Transactions on Internet Technology (TOIT), 2021. 21(4): p. 1-22.
25. Theodouli, A., et al. On the design of a blockchain-based system to facilitate healthcare data sharing. 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). 2018. IEEE.
26. Zheng, X., et al. Blockchain-based personal health data sharing system using cloud storage. in 2018 IEEE 20th international conference on e-health networking, applications and services (Healthcom). 2018. IEEE.
27. Puthal, D., et al., The blockchain as a decentralized security framework [future directions]. IEEE Consumer Electronics Magazine, 2018. 7(2): p. 18-21.
28. Linn, L.A. and M.B. Koo. Blockchain for health data and its potential use in health it and health care related research. in ONC/NIST Use of Blockchain for Healthcare and Research Workshop. Gaithersburg, Maryland, United States: ONC/NIST. 2016.
29. Vora, J., et al. BHEEM: A blockchain-based framework for securing electronic health records. in 2018 IEEE Globecom Workshops (GC Wkshps). 2018. IEEE.
30. Halloush, Z.A. and Q.M. Yaseen. A blockchain model for preserving intellectual property. in Proceedings of the Second International Conference on Data Science, E-Learning and Information Systems. 2019.

**ISSN:** 2776-1010 Volume 3, Issue 9, Sep., 2022

31. Dasaklis, T.K., F. Casino, and C. Patsakis. Blockchain meets smart health: Towards next generation healthcare services. in 2018 9th International conference on information, intelligence, systems and applications (IISA). 2018. IEEE.
32. Pavithran, D., et al., Towards building a blockchain framework for IoT. Cluster Computing, 2020. 23(3): p. 2089-2103.
33. Eklund, P.W. and R. Beck. Factors that impact blockchain scalability. in Proceedings of the 11th international conference on management of digital ecosystems. 2019.
34. Dang, H., et al. Towards scaling blockchain systems via sharding. in Proceedings of the 2019 international conference on management of data. 2019.
35. Zhang, S. and J.-H. Lee, Analysis of the main consensus protocols of blockchain. ICT express, 2020. 6(2): p. 93-97.
36. Li, P., et al. Crux—A New Fast, Flexible and Decentralized Consensus Algorithm with High Fault Tolerance Rate. in International Conference on Smart Blockchain. 2018. Springer.
37. Muzammal, M., Q. Qu, and B. Nasrulin, Renovating blockchain with distributed databases: An open source system. Future generation computer systems, 2019. 90: p. 105-117.
38. Dubovitskaya, A., et al., Applications of blockchain technology for data-sharing in oncology: results from a systematic literature review. Oncology, 2020. 98(6): p. 403-411.
39. Hughes, L., et al., Blockchain research, practice and policy: Applications, benefits, limitations, emerging research themes and research agenda. International Journal of Information Management, 2019. 49: p. 114-129.
40. Zeng, J., J. Zhang, and Y. Liu. Blockchain based smart park: Cleaning management. in Proceedings of the 2019 2nd International Conference on Blockchain Technology and Applications. 2019.
41. Bore, N., et al. Towards blockchain-enabled school information hub. in Proceedings of the Ninth International Conference on Information and Communication Technologies and Development. 2017.
42. Zhang, L., Y. Huang, and T. Jiang. High-speed railway environmental monitoring data identity authentication scheme based on consortium blockchain. in Proceedings of the 2019 2nd International Conference on Blockchain Technology and Applications. 2019.
43. Jararweh, Y., S. Otoum, and I. Al Ridhawi, Trustworthy and sustainable smart city services at the edge. Sustainable Cities and Society, 2020. 62: p. 102394.
44. Abdelhamid, M. and G. Hassan. Blockchain and smart contracts. in Proceedings of the 2019 8th International Conference on Software and Information Engineering. 2019.
45. Fatrah, A., et al. Proof of concept blockchain-based voting system. in Proceedings of the 4th International Conference on Big Data and Internet of Things. 2019.
46. Awalu, I.L., P.H. Kook, and J.S. Lim. Development of a distributed blockchain evoting system. in Proceedings of the 2019 10th International Conference on E-business, Management and Economics. 2019.
47. Liu, J., et al. Blockchain for data science. in Proceedings of the 2020 The 2nd International Conference on Blockchain Technology. 2020.