

Blockchain Technology and its applications:A review

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Abstract:

Blockchain as a decentralized and distributed technology, is supposed to make a strong impact generating a wide range of opportunities in various applications. The blockchain is a platform with a scripting language that can solve many use cases other than cryptocurrencies. As blockchain can protect the integrity of data storage and ensure process transparency. The blockchain is so far well known for its potential applications in the financial and banking sectors. In recent years blockchain technology has shown its adaptability in many fields such as supply chain management, healthcare and so on. In this paper, first an overview of the blockchain technology is explained and all various applications of blockchain technology are explored.

Keywords: *Blockchain, cryptocurrency, supply chain management, IoT*

I. INTRODUCTION

Today, advancements are a necessary piece of the world economy. As indicated by McKinsey Global Institute investigation (2013), 12 troublesome advances will essentially change the circumstance in the worldwide market by 2025. Their potential monetary effect is evaluated to be somewhere in the range of 14 and 33 trillion US dollars. These 12 high-potential advancements talked about in the Institute's investigation do exclude Blockchain. In any case, despite the fact that being out of the rundown, Blockchain may turn into a dull steed in the challenge, since it will impact the vast majority of the recorded advances, for example Cloud, Internet of Things, and Autonomous vehicles. Numerous sources which are committed to innovation industry have begun to impart the insight that Blockchain itself may end up a standout amongst the most dominant advances of tomorrow. Right off the bat, the innovation turned out to be notable in 2008 when it was conceptualized by either an individual or a gathering of authors of Bitcoin under the name of Satoshi Nakamoto in an examination paper titled "Bitcoin: A Peer-to-Peer Electronic Cash System"[1]. Blockchain was utilized as a center part for Bitcoin cryptographic money. There, the idea of innovation was alluded to as "square" and "chain" Firstly, the innovation turned out to be outstanding in 2008 when it was conceptualized by either an individual or a gathering of

originators of Bitcoin under the name of Satoshi Nakamoto in an examination paper titled "Bitcoin: A Peer-to-Peer Electronic Cash System". Blockchain was utilized as a center part for Bitcoin digital currency. There, the idea of innovation was alluded to as "square" and "chain" The inspiration of leading this investigation is to break down the Blockchain as a central innovation, which is as of now a piece of Bitcoin as well as not yet considered as "another Internet". This investigation means to locate the present position of Blockchain at the worldwide mechanical scene and to talk about potential outcomes of the innovation execution.

Regardless of being a notable innovation, there were a few different developments other than Bitcoin's Blockchains, which conveyed some imperative updates to the Blockchain innovation. Ethereum's Blockchain has presented the stage for Blockchain-based arrangements improvement and actualized 19 savvy contracts to the innovation, which made it progressively adaptable and variable by empowered redefining conditions on the program. In this manner, the Blockchain innovation can be adjusted in numerous ventures and arrangements and altogether change them by giving straightforwardness, nonappearance of an outsider and secure P2P connections. [2]

The remaining parts of this paper are organized as follows. Section 2 describes the Blockchain technology. Section 3 discusses the various applications of blockchain technology.

II. OVERVIEW OF BLOCKCHAIN TECHNOLOGY

The blockchain in its basic form can be seen as the distributed, decentralized, transparent and chronological database of transactions [1]. The data in the blockchain is divided into blocks. Each block consists of data, previous hash and present hash. Hash is like a fingerprint of the data in the block. The first block is called the Genesis block. Each block is dependent upon the previous one. These blocks are cryptographically linked to each other by the hash function hence the name blockchain. The framework in which a blockchain fills in as the database includes hubs [3]. These hubs are in charge of attaching new squares to the blockchain. Another square must be affixed after all hubs in the framework achieve an accord. The blockchain innovation brings new idea which grasps new mechanical improvements and movements the power from one to many, or from focal idea to a dispersed one.

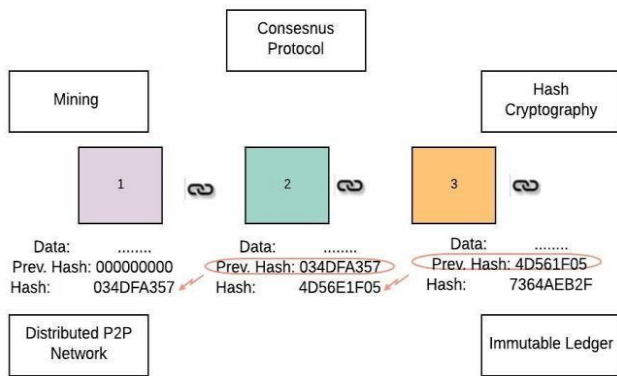


Fig. 1. Overview of Blockchain technology

A. HASH CRYPTOGRAPHY:

Secure Hash Algorithm (SHA): It is one of the cryptographic hash functions. A cryptographic hash [4] is like a signature for any digital document. Hash is a one-way function, it cannot be decrypted back. There are different SHA algorithms like SHA 256, SHA 512, SHA 3 etc. where 256, 512 and 3 represent the bits it takes up in the memory. If we modify the data in the block then the hash generated will change completely. Hence exhibiting Avalanche effect. The five requirements for the hash algorithm are one-way, deterministic, fast computation, avalanche effect, must withstand collision [5].

B. Immutable Ledger

Ledger is used to keeping records. Immutable ledger [6] refers to a ledger that cannot be corrected, it remains permanent. Because of any change in one block the succeeding blocks have to be changed that leads to the breaking of the chain. Hence it becomes difficult for anyone who wants to manipulate the data.

C. Distributed Peer-to-Peer Network

Distributed p2p network [8] consists of n-number of computers so the entire blockchain will be stored across the network in many systems. If any block is hacked then the other computers in the network communicate with each other regarding modification in the blockchain. Once the modification is detected in the network then the correct values will be copied and hence data will be restored. Therefore, the hacker has to attack more than 50% of the blockchain at a time only then they can hack successfully. Hence additional security comes into picture where technology brings trust in the trustless network.

D. MINING

A block stores multiple transactions. Mining is all about nonce. Nonce gives extra control and flexibility. we can change the hash by changing nonce. The miners solve the cryptographic puzzle to find the correct hash. The miners work to calculate the correct nonce by changing different nonce values. For the block to be added in the blockchain the hash generated should be less than target and the hash should start with leading zeroes.

When two miners perform mining at the same time for the same block then the byzantine problem occurs. The blocks

which are not the majority are called orphaned blocks. In this case the transaction doesn't take place in the network.

E. CONSENSUS PROTOCOL

The protocol regulates the computation of new blocks [7]. The block is shared among all nodes in the system, the protocol is responsible to keep the blockchain valid. The protocol regulates how the blockchain is used for a specific purpose. Consensus protocol [8] provide defense against attackers. Different types of consensus protocols include proof of work, proof of stake, proof of elapsed time etc.

III. APPLICATIONS OF BLOCKCHAIN

In this section, the implementation of blockchain technology in different areas are thoroughly discussed. The applications are categorized as healthcare, supply chain management, finance, IoT and other various other implementations.

Healthcare

In healthcare various information regarding patients is spread across a number of systems and sometimes the information will not be accessible when required [3]. The present healthcare system is inadequate to handle information exchange. one of the biggest thing in healthcare is the lack of a central administrator. This issue can be addressed by using blockchain technology which eliminates the need of a central administrator. Since healthcare deals with confidential patient data and requires quick access to information .Blockchain can streamline these medical records and enable their sharing in a secure way. Blockchain offers access security, scalability data privacy and data sharing[14].The concept of blockchain in healthcare is disruptive-but it wont be an elixir to drown down the issues of data management.Five ways blockchain can benefit healthcare are a single longitudinal patient record, Master patient indices, claim adjudication, supply chain management and interoperability[9]. Tanesh kumar et. al [10] explore various applications and requirements ,the various obstacles and challenges faced for implementing blockchain in healthcare are also discussed and smart contracts based system is introduced for defining the predefined agreement among various stake holders. Artificial intelligence(AI) and blockchain coupled electronic healthcare records (EHR) management system are proposed by Youssef wehbe et . al [11] to provide a platform that leverages AI and Blockchain in healthcare. Kai Zheng et. al

[12] use continuous time Markov chain(CTMC) models to simulate the time response of Practical byzantine fault tolerance(PBFT) -based healthcare blockchain network for optimization design of blockchain network by analyzing nodes. To evaluate the efficacy of healthcare remedies in a manner of citizen science Junseok park et. al [13] presented CORUS a blockchain based crowdsourcing on a cloud

computing platform. Shan jiang et. al[15] proposed BloCHIE a blockchain based platform for healthcare information exchange to overcome the problem of data exchange in healthcare. Majorly blockchain potential for healthcare depends on how willing healthcare organizations are to create the required technical infrastructure.

Supply chain management

Supply chain management includes integrated planning as well as the execution of different processes. This includes material flow, data flow just as financial flow. This scheme involves administration of the stream of merchandise, administrations, and data including the capacity and development of crude materials, building items just as undeniable completed products starting with one point then onto the next is called as inventory network the executives. for all intents and purposes keeping up a production network is a repetitive undertaking notwithstanding for private ventures. The interconnectivity of various components in the inventory network bit by bit turns out to be progressively wasteful. In a request to determine these blockchain is investigating better approaches to change the general game. Blockchain can be connected to numerous difficulties of the Supply Chain industry, for example, convoluted record keeping and following of items. As a less corruptible and better-robotized option in contrast to concentrated databases. One of the most engaging advantages of utilizing blockchain for information is that it enables the information to be progressively interoperable. As every item can be followed continuously, the odds of removals are uncommon. Blockchain offers adaptability through which any expansive database is available from various areas from around the globe. It likewise gives higher guidelines of security and the capacity to redo as per the information feed. Moreover, blockchains can be made in a private way too which will enable the information to be gotten to unequivocally between the gatherings who have the authorization for it. The benefit of embracing blockchain innovation can be taken from the way that it can possibly interface diverse records and information focus while keeping up the information uprightness among different members. The properties of straightforwardness and permanence of blockchain innovation make it valuable for wiping out cheats in store network and keeping up the uprightness of the system. Mitsuaki nakasumi [16] proposed another blockchain conspire for data sharing and proposed a blockchain based solution to overcome the problems of the supply chain such as double marginalization and information asymmetry in supply chain management. Miguel Pincheira caro et. al [17] presents Agri Block IoT, a completely decentralized, blockchain-based recognizability answer for Agri-Food store network the board, ready to consistent coordinate IoT gadgets delivering and expending advanced information along the chain. Si chen et. al[18] talk about examine how to enhance the production network quality administration by embracing the blockchain innovation, and propose a system for blockchain-based inventory network quality administration. Stamp H. Meng et. al [19] proposed an improved appraisal show for real time prescient conveyance execution metric and furthermore planned a blockchain.

Finance

The blockchain is now an exciting new alternative to traditional currency, brought together managing an account, and exchange techniques that are not just changing the manner in which we handle budgetary exchanges, yet in addition elective uses that will change the world. To put it plainly, blockchain is a conveyed record that keeps up a ceaselessly developing rundown of each exchange over each system circulated more than a huge number of PCs. This makes it practically difficult to hack, changing the manner in which keeping money is finished. The blockchain is the vision of designers who trusted that the present keeping money framework had imperfections. Specifically, they saw banks going about as outsiders and stealing exchanges charges as superfluous, and they laughed at the possibility that installment approval and settlement could take up to five business days in cross-outskirt exchanges. With blockchain, ongoing exchanges are a probability (even crosswise over outskirts), while banks are let well enough alone for the condition completely, apparently decreasing exchange fees. Ever since Satoshi Nakamoto distributed a development he called bitcoin[1] in 2009, the first cryptocurrency. Cryptocurrency has its very own money (coin). Mining is the way toward bringing another square into blockchain. Every hub utilizes blockchain to check whether the coin is real or on the off chance that it has not spent as of now. Before the exchange records are attached into the blockchain, a more noteworthy number of members achieve an understanding. The mining procedure is an asset concentrated errand, in this manner makes it intense for an aggressor to approve an invalid exchange. Each mined- square is confirmed to check whether it has whether a legitimate accord convention. The followings are the predominant strides in digital currency: (I) a created location (open key) is accessible for a client who has a wallet, (ii) a private key is doled out to the wallet. It is utilized to sign the exchange and demonstrating proprietorship, (iii) the payer sends the coin to the payee utilizing given the location and sign it utilizing payer's private key, lastly (iv) the exchange is approved by means of mining process. Few other cryptocurrencies include Litecoin [20], Peercoin [21], Primecoin [22], Ripple [23], Ethereum [24], Permacoin [25], Blackcoin [26], Auroracoin [27], Darkcoin [28], and Namecoin [29] etc.

Internet of Things (IoT)

The revolution of information technology has entered an unprecedentedly important stage of networking development: data network almost achieves "connection of objects". This stage is known as the third wave of the world's information industry development following the computers and the Internet — the age of the Internet of Things. Because of the distributed nature of blockchain it can be implemented in IoT. Blockchain and internet of things are key technologies that will have a major impact in the industry. These two technologies will improve efficiency, provide new business opportunities, address regulatory requirement, improve transparency and

visibility[30]. Leveraging blockchain for IoT data offers new ways to automate business processes among partners without setting up a complex and expensive centralized architecture. Three key benefits of using blockchain for IoT is to build trust, To reduce cost and accelerate transactions .Madhusudan Singh et. al [31] discusses how blockchain technology can be used to make more secure and trustable IoT model. .Bing Mo et. al [32] presents a blockchain- based Internet of Things solution, where RFID chips with built-in asymmetric encryption algorithm and scanners uploading information directly to the blockchain. The comprehensive survey of blockchain technology for IoT is presented and various issues and challenges are discussed [33]. In order to address the applicability of blockchain technology to ensure the security of data transmitted and received by the node in IoT, Yash Gupta et. al [34] propose a blockchain consensus devices and also propose a model for implementing IoT security on top of blockchain models.

Other implementations

In this section, the current implementation of blockchain in many areas such as network security, defense, Data security in cloud computing, education, big data, are discussed.

With the purpose of identifying cyber threats and possible incidents, intrusion detection systems (IDS) are widely deployed in various computer networks. As blockchain technology can protect the integrity of data storage and ensure process transparency, it has the potential to be applied in intrusion detection domain. In order to enhance the detection capability of a single IDS, collaborative intrusion detection systems have been developed [35] [36].

The scope and the detailed analysis of the idea of utilizing blockchain technology as a viable solution for ensuring integrity and provenance of data to suit military operations using and maintaining the sustainability of the networks is discussed in [37]. Data has become an inevitable factor in cloud computing. The word data eventually seeks its issue on privacy and security. With the rise of new technologies, the need for data storage has increased. Massive increase in the datasets has led to the evolution of cloud storage. The benefits of cloud computing are immense, but on the contrary there is an increasing risk to the security of the data stored in the cloud. This paper [38] deals with a survey on the security issues which highlights the effectiveness of security that has been implied in the forms of cloud computing and blockchain technologies. This paper [39] describe how permissioned Blockchain can be applied to a specific educational use case—decentralized verification of academic credentials. The proposed Blockchain-based solution, named ‘CredenceLedger’, is a system that stores compact data proofs of digital academic credentials in Blockchain ledger that are easily verifiable for education stakeholders and interested third party organizations. This paper [40] presents the novel solutions associated with some of the Big Data areas that can be empowered by the Blockchain technology. This paper [41] presents a systematic study on the security threats to blockchain and survey the corresponding real attacks by examining popular blockchain systems and also review the security

enhancement solutions for blockchain, which could be used in the development of various blockchain systems.

SUMMARY.

The Blockchain is a relatively young technology, which was firstly conceptualized about ten years ago as a part of Bitcoin cryptocurrency. It has been only in the last years that it has become a global phenomenon as an independent technology and revolutionary discovery. The blockchain is a result of several decades of continuous work by cryptographers, algorithm’s researchers and computer scientists. The technology is mainly used for fueling secure digital payments. On the other hand, the foundational technology has a huge potential to change almost all of the major areas of human lives. The technology has a huge potential for development and application. Depending on the area of its implementation, Blockchain could solve some obstacles faced and evolve the core processes. Each of industries earlier or later will face the changes caused by the Blockchain. There is no technological and economic reason to force the development, as it is a foundational, not a disruptive technology. There are tremendous advantages of blockchain such as speed, robustness, openness, and so forth. However, blockchain is not an universal cure for all problems and there are several issues that have been identified such as financial transaction for criminal activities, legal aspects, and other economic risks. Blockchain has become one of the promising technology in the future if well exploited. This paper offers an understanding of the current blockchain research and its real-world implementations

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References

1. S. Nakamoto. (2008). Bitcoin: A Peer-to-Peer Electronic Cash System. [Online]. Available: <http://bitcoin.org/Bitcoin.pdf>
2. Khudnev, Evgenii, 2017, “Blockchain: Foundational Technology to change the world, Bachelor of business administration, LAPIN AMK, Lapland university of applied sciences.
3. Bayu Adhi Tama, Bruno Joachim Kweka, Youngho Park, Kyung- Hyune Rhee, “A Critical Review of Blockchain and Its Current Applications,” in International Conference on Electrical Engineering and Computer Science (ICECOS) 2017.
- 4 Karl wust and Arthur Gervais, ”Do you need a blockchain?”, Crypto Valley conference on Blockchain (CVCBT) June 2018

5. R. Goyal and V.Goyal, "overcoming cryptographic impossibility results using blockchains", in proc. 15th Int. Conf. TCC, Baltimore, MD, USA, 2017, pp.529-561.
6. Walport, M.: Distributed ledger technology: Beyond blockchain. UK Government office for Science (2016)
7. N. Szabo. Smart Contracts: Building Blocks Digital Markets. Accessed: Oct. 15, 2017. [online]. Available: <http://www.fon.hum.uva.nl/rob/courses/informationInSpeech/CDR>
OM/Literature/LOTwinterschool2006/szabo.best.vwh.net/smart_contracts_2.html
8. Baliga, A.: Understanding Blockchain Consensus Models. Tech. rep., Persistent Systems Ltd. (2017)
9. Sofia Alexaki, George Alexandris, Vasilis Katos, Nikolaos E. Petroulakis, "Blockchain-based Electronic Patient Records for Regulated Circular Healthcare Jurisdictions," in 2018 IEEE 23rd International Workshop on Computer Aided Modeling and Design of Communication Links and Networks (CAMAD).
10. Tanesh Kumar, Vidhya Ramani, Ijaz Ahmad, An Braeken, Erkki Harjula, Mika Ylianttila, "Blockchain Utilization in Healthcare: Key Requirements and Challenges," in 2018 IEEE 20th International Conference on e-Health Networking, Applications and Services (Healthcom).
11. Youssef Wehbe, Mohamed Al Zaabi, and Davor Svetinovic, "Blockchain AI Framework for Healthcare Records Management: Constrained Goal Model," in 26th Telecommunications forum TELFOR 2018.
12. Kai Zheng, Ying Liu, Chuanyu Dai, Yanli Duan, Xin Huang, "Model Checking PBFT Consensus Mechanism in Healthcare Blockchain Network," in 2018 9th International Conference on Information Technology in Medicine and Education.
13. Junseok Park, Seongkuk Park, Kwangmin Kim, Doheon Lee, "CORUS: Blockchain-Based Trustworthy Evaluation System for Efficacy of Healthcare Remedies," in 2018 IEEE International Conference on Cloud Computing Technology and Science (CloudCom).
14. Anastasia Theodouli, Stelios Arakliotis, Konstantinos Moschou, Konstantinos Votis, Dimitrios Tzovaras, "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.
15. Shan Jiang, Jiannong Cao, Hanqing Wu, Yanni Yang, Mingyu Ma, Jianfei He, "BLoCHIE: a BLOCKchain-based platform for Healthcare Information Exchange," in 2018 IEEE International Conference on Smart Computing.
16. Mitsuaki Nakasumi, "Information Sharing for Supply Chain Management based on Block Chain Technology," in 2017 IEEE 19th Conference on Business Informatics.
17. Miguel Pincheira Caro, Muhammad Salek Ali, Massimo Vecchio and Raffaele Giuffreda, "Blockchain-based Traceability in Agri-Food Supply Chain Management: A Practical Implementation," in 2018 IoT Vertical and Topical Summit on Agriculture –Tuscany (IOT Tuscany).
18. Si Chen, Rui Shi, Zhuangyu Ren, Jiaqi Yan, Yani Shi, Jinyu Zhang, "A Blockchain-based Supply Chain Quality Management Framework," in The Fourteenth IEEE International Conference on e-Business Engineering.
19. Mark H. Meng, Yaou Qian, "A Blockchain Aided Metric for Predictive Delivery Performance in Supply Chain Management," in International Conference on Service Operations and Logistics, and Informatics (SOLI 2018).
- [20]. C. Lee, "Litecoin," 2011.
- [21] — "Peercoin—secure & sustainable cryptocoin," Aug-2012 [Online]. Available: <https://peercoin.net/whitepaper>.
- [22] S. King, "Primecoin: Cryptocurrency with prime number proof-of-work," July 7th, 2013.
- [23] D. Schwartz, N. Youngs, and A. Britto, "The ripple protocol consensus algorithm," Ripple Labs Inc White Paper, vol. 5, 2014.
- [24] G. Wood, "Ethereum: A secure decentralised generalised transaction ledger," Ethereum Project Yellow Paper, vol. 151, 2014.
- [25] A. Miller, A. Juels, E. Shi, B. Parno, and J. Katz, "Permacoin: Re-purposing bitcoin work for data preservation," in IEEE Symposium on Security and Privacy (SP). IEEE, 2014, pp. 475–490.
- [26] P. Vasin, "Blackcoins proof-of-stake protocol v2," 2014.
- [27] D. Cawrey, "Auroracoin airdrop: Will iceland embrace a national digital currency," CoinDesk, March, vol. 24, 2014.
- [28] E. Duffield and K. Hagan, "Darkcoin: Peertopeer cryptocurrency with anonymous blockchain transactions and an improved proof of work system," Mar-2014 [Online]. Available: <https://www.dash.org/wpcontent/uploads/2014/09/DarkcoinWhitepaper.pdf>, 2014. International Conference on Electrical Engineering and Computer Science (ICECOS) 2017
- [29] H. Kalodner, M. Carlsten, P. Ellenbogen, J. Bonneau, and A. Narayanan, "An empirical study of namecoin and lessons for decentralized namespace design," in Workshop on the Economics of Information Security (WEIS). Citeseer, 2015.
- [30]. Dennis Miller, "Blockchain and the Internet of Things in the Industrial Sector," IT Professional Volume: 20, Issue: 3, May./Jun. 2018
- 31 Madhusudan Singh, Abhiraj Singh, Shiho Kim, "Blockchain: A Game Changer for Securing IoT Data," 2018 IEEE 4th World Forum on Internet of Things (WF-IoT)
- 32 Bing Mo, Kuiren Su, Songjie Wei, Cai Liu, Jianping Guo, "A Solution for Internet of Things based on Blockchain Technology," in International Conference on Service Operations and Logistics, and Informatics (SOLI 2018).
33. Mohamed Amine Ferrag, Makhlof Derdour, Mithun Mukherjee, Abdelouahid Derhab, Leandros Maglaras, Helge Janicke, "Blockchain Technologies for the Internet of Things: Research Issues and Challenges," IEEE Internet of Things Journal, November 2018
34. Yash Gupta, Rajeev Shorey, Devadatta Kulkarni and Jeffrey Tew, "The Applicability of Blockchain in the Internet of Things," International Conference on Communication Systems & Networks (COMSNETS) Jan 2018
35. Weizhi meng, Elmar wolfgang tischhauser, qingju wang, yu wang and jinguang han, "When intrusion detection meets blockchain technology: A review", Research Challenges and

Opportunities in Security and Privacy of Blockchain Technologies, IEEE access, Vol:6, 1, 2018

36. N. Alexopoulos, E. Vasilomanolakis, N. R. Ivanko, M. Muhlhäuser, "Towards blockchain-based collaborative intrusion detection system", in Proc. Int. Infrastructure Secur., 2017, pp. 1-12.

37. Amool Sudhan and Manisha J. Nene, "Employability of blockchain technology in defense applications", Proceedings of the International Conference on Intelligent Sustainable Systems (ICISS 2017)

38. S. Prianga, R. Sagana and E. Sharon, "Evolutionary survey on data security in cloud computing using blockchain. IEEE International Conference on System, Computation, Automation and Networking (ICSCAN) July 2018

39. Rodelio Arenas, Proceso Fernandez, "CredenceLedger: A Permissioned Blockchain for Verifiable Academic Credentials," in 2018 IEEE International Conference on Engineering Technology and Innovation (ICE/ITMC).

40. Elena Karafiloski, Anastas Mishev, "Blockchain Solutions for Big Data Challenges," in IEEE EUROCON 2017, 6-8 July 2017, Ohrid, R. Macedonia.

41. Xiaoqi Li, Peng Jiang, Ting Chen, Xiapu Luo, Qiaoyan Wen, "A Survey on the security of Blockchain systems," in Future Generation Computer Systems (2017).