Journal of Telematics and Informatics (JTI)
Vol.7, No.2, June 2019, p. 69~79
ISSN: 2089-3272

A Review of Blockchain: How Does It Work, Applications, and Challenges

Ade Kurniawan[1], Winda Andrini Wulandari[2], Raymond Erz Saragih[3], Ihsan Verdian[4]
[1,3,4]Department of Informatics Engineering, Universal University
Kompleks Maha Vihara Duta Maitreya, Batam, Kepulauan Riau
[2]Department of Information Technology, Universitas Lambung Mangkurat.
Jl. Brigjen H. Hasan Basri No.3, Kota Banjarmasin, Kalimantan Selatan
e-mail: ade.kurniawan@uvers.ac.id [1], wul4nd4r1.1991@gmail.com [2] ,
raymonde.saragih@gmail.com [3], ihsanverdian@yahoo.com [4]

Abstract

Behind Bitcoin's, there is a technology that becomes its fundamental part, which is Blockchain. Bitcoin is the first cryptocurrency in the world. At present, blockchain technology is the subject of discussion and research among developers, business people and researchers. Basically, blockchain technology functions as a digital 'ledger' that records every transaction that occurs and what makes blockchain interesting is, data that has been recorded in it cannot be changed. Furthermore, various blockchain-based applications began to emerge, and are used in various fields, the first to implements blockchain technology is digital currency transactions, other fields, such as the Internet of Things, government, health services, education, and industries. However, like other emerging technologies, blockchain technology still faces several challenges such as scalability and security. To deepen the knowledge about blockchain technology, a literature study is needed using the Literature Review method. This research uses literature sources from Scopus reputable institutions, Thomson Reuters / Web of Science, Directory of Open Access Journals (DOAJ), EBSCO, and Google Scholar. The contribution of this paper is to convey how Blockchain technology works, the applications and challenges ahead that will be faced by blockchain technology.

Keywords*: Blockchain, Implementation, Internet of Things, Systematic Literature Review*

1. Introduction

The world is becoming digital, with the presence of the Internet that demands all business processes, government, and even households running fast, precisely, safely, and less expensive [1]. Furthermore, in economic history, people will not forget the economic crisis event that occurred in 2008 [2]. The 2008 economic crisis was seen by economist as the worst financial crisis since the Great Depression (1930s) [3][4]. This crisis caused the economy to deteriorate and threatened the collapse of major financial institutions. This makes the government in various countries have to take an action to save big banks from bankruptcy. The economic crisis in 2008 happened because the financial and accounting instruments used to maintain the integrity of the entire financial system was too complicated and could not be used efficiently. Trust, which is the fundamental of all financial systems, began to disappear in 2008 [4]. As a result of the event, a paper appeared entitled "Bitcoin: A Peer-to-Peer Electronic Cash System" with writer named Satoshi Nakamoto [5]. The emergence of Satoshi's paper introduced the first cryptocurrency, called "Bitcoin" to the public, which was then recognized by people to date. The interesting thing about Satoshi's writing is the ability of Bitcoin to change the financial transaction system used.

Bitcoin is a digital currency that breaks down the conventional money transaction system, making it known to ordinary people. However, behind Bitcoin's success, there is a technology which becomes its foundation called Blockchain. Blockchain technology turns out not only to be used for Bitcoin (digital currency) but has the potential to be applied in other fields [6]. This is because blockchain is able to offer features that are not offered by the current centralized system,

including transaction data forgery, hacker attacks and mediators [7]. With blockchain technology, mediator can be removed, transaction data cannot be changed, and hackers will almost impossible to hack. This is what makes blockchain an innovation technology that can be applied in various fields.

Blockchain technology is able to bring new innovations to the current system. However, blockchain is still considered a new technology. So there needs to be a discussion about this technology, its applications and its challenges. This paper is intended for readers who want to start research on the Blockchain field that focuses on how Blockchain technology works, explore applications in various fields and challenges of blockchain technology.

The structure of this paper are as follows: Chapter II briefly discusses the methodology used in writing this paper, namely the Literature Review methodology. Chapter III discusses the basic theory of blockchain. Chapter IV discusses the applications of blockchain technology. In Chapter V, contains the challenges faced by blockchain technology and Chapter VI is the conclusions of this paper.

2. Research Method

Literature Review is a study which purpose is to make a summary and analysis of various information published in a field of research. A literature review is considered good if it follows the latest research trends and comprehensively addresses the current state of the topic discussed [8]. In making a literature review, there must be a purpose to be attained. According to [8], there are seven purposes in making a literature review:

1. In order to know how a paper contributes to the understanding of a subject being studied.
2. In order to know the relationship between one's research with other's research.
3. In order to describe the deficiencies found in previous studies.
4. In order to provide a solution to different understanding in previous studies which are contradictory.
5. In order to describe what previous researchers have discussed to prevent other authors from duplicating the research of previous researchers.
6. In order to determine the state of the art of current research as a measure for the next research.
7. In order to know the current position of a paper in the same research field.

In writing a literature review, there are steps that has to be taken by an author. Machi and McEvoy [9] explained that there are six steps that has to be taken. Figure 1 shows those six steps.

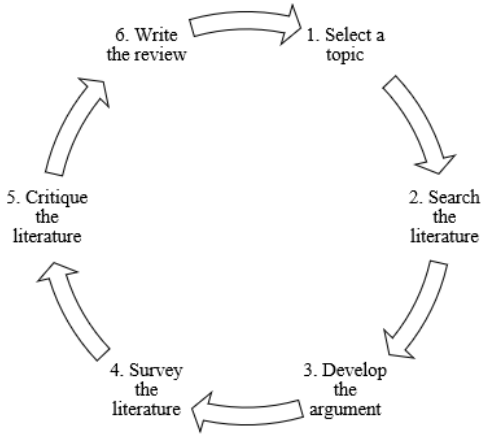

Figure 1. Six steps in writing a literature review

1. Select a Topic

In this step, the author should choose a topic to be discussed in the literature review. To determine which topic will be discussed, an author may search through dissertations, theses, research reports, websites, books, films, or papers [10].

2. Search the Literature

Once the author has determined the topic that will be discussed, the next step is to search the literature related to the chosen topic. In searching the literature, author may use skimming,

scanning, and mapping technique [9]. Then, the author organizes and manage materials that are collected into bibliography organizing software, such as Mendelley, Zotero, Docear and others.

3. Develop the argument

The next step taken by the author is to develop an argument or research questions. There are two types of argument that can be developed: (i) The discovery argument (ii) Argument of defense [10].

4. Survey the literature

In this step, the author identifies the main ideas of literatures obtained, discovers important parts of a book's chapter or articles and sources of the literatures the author chooses [10].

5. Critique the literature

At this step, the author provide insights into the findings obtained from the previous step. The findings are then arranged logically to form arguments that support arguments made by the author at the third step [9].

6. Write the review

In this last step, the author arranges the findings into a literature so as to extend knowledge and open up new viewpoint to the audience who reads it [10].

In this section, it is explained the results of research and at the same time is given the comprehensive discussion. Results can be presented in figures, graphs, tables and others that make the reader understand easily [2], [5]. The discussion can be made in several sub-chapters.

Blockchain is a digital ledger that is distributed in a peer-to-peer manner, which has function to store transaction data in a network [7][11]. Blockchain is secured using cryptography, where data can only be added, immutable, and can only be updated through consensus or mutual agreement between the nodes involved [12].

According to [13], there are three definitions of blockchain, from technical point of view, from business point of view, and legal point of view. The explanation of these three definitions are as follow:

a. From technical point of view, blockchain can be defined as a back-end database that serves to store a digital ledger that is distributed peer to peer and can be accessed publicly [13].
b. From business point of view, blockchain defined as a platform where parties involved can exchange assets and transact, without the need of a third party as a trusted intermediary in conducting the transaction process [13][12].
c. From legal point of view, blockchain serves as a mechanism that can validate a transaction, therefore intermediaries are no longer needed [13].

The name 'blockchain' is derived from the way the transactions data are stored. Blocks containing transactions data are connected to each other to form a chain that is unbreakable [7]. The length of the chain will increase overtime as new blocks will continue to be added [14]. A block contains a number of transactions that later will be added to the blockchain [12][15]. The size and structure of a block depends on the type and structure of the blockchain used. In general, the attributes of a block are block headers, a hash pointer that points to the hash of the previous block, time stamp, nonce, transaction counter, transactions data and other attributes [12][16][15]. Figure 2 – adapted from [5][12][14], shows the general structure of a blockchain and the structure of a block. In Figure 2, there is a block called genesis block, which is the first block added into a blockchain [12], while the next block is added after a number of new transactions occurred.

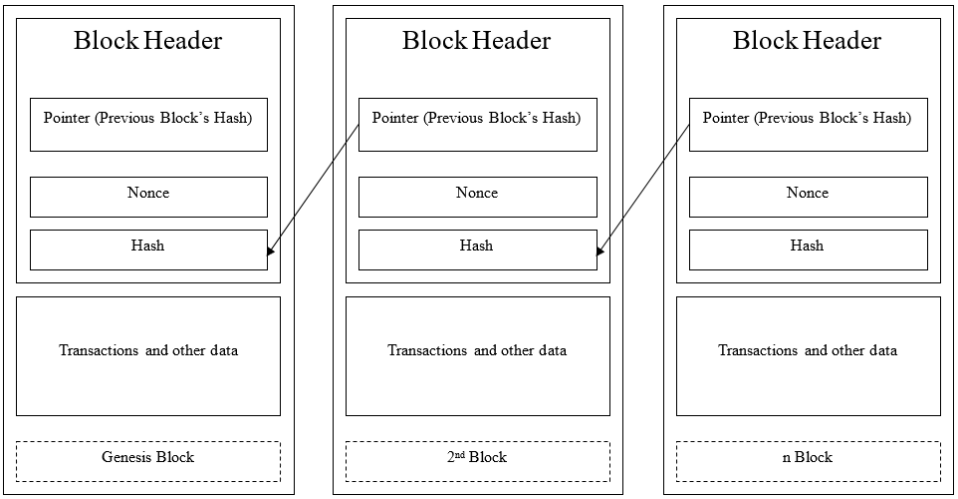

Figure 2. General Blockchain structure

The explanation of block structure is as follows [12][15]:

1. Block header

The size of block header is about 80 byte [5]. Block header has three metadata of a block. The first meta data is pointer that refers to the previous block's hash. The second meta data contains the difficulty of a block target, which is the difficulty level of the Proof-of-Work algorithm of the block; timestamp is the time when a new block is created, that has the Unix epoch time format; and nonce, counters used in the Proof-of-Work algorithm, where the numbers are repeatedly replaced by miners in an effort to produce a hash that meets the difficulty target. The third meta data is the Merkle Root, the hash of the root Merkle Tree of a block [15][12].

2. Transactions

Transactions are the fundamental data inside a block in blockchain. Transactions represent a transfer of value from one party to another [12]. Transactions can be seen as a row inside a ledger. Each transaction may contain one or more entries (debits), while on the other side of the transaction, there may be one or more outputs (credits). The sum between input (debit) and output (credit) should not be the same. Output (credit) will have less amount than input (debit). The difference between the total of inputs and outputs is the cost taken by the miner for his services in adding block to the blockchain [15].

Blockchain is known to have several special characteristics. According to [17], some of the main characteristics of blockchain are as follows:

1. Decentralization

In a centralized transaction system, each transaction must be validated through a trusted intermediary system, such as a bank. This results in the increased costs and a decrease in the processing ability of the server the system used. Unlike the existing transaction system, on blockchain, the presence of a third party is no longer necessary. This is because of the consensus algorithm contained in the blockchain, whose function is to maintain consistency of existing data in a distributed network.

2. Immutable

Transactions in a relatively short period of time can be validated and if any unauthorized transaction is found by the miner, the transaction will not be added to the blockchain. If a transaction has been added into the blockchain, the transaction will not be able to be deleted or changed.

3. Confidentiality

The identity of a participant who is already registered in a blockchain will not be displayed openly to other participants, because they have been given a unique identity that was created automatically [7].

4. Auditable

Since every participant involved in a blockchain can access the same transaction records, they can check the validity of a transaction and verify the parties involved in a transaction.

In practice, blockchain is divided into several types:

1. Public Blockchain

Public Blockchain is an open blockchain, where everyone can join and participate in the network and become one of the nodes in the network. The merged party can keep records of existing transactions [12]. The examples of public blockchain are Bitcoin and Ethereum.

2. Private Blockchain

Private Blockchain is a blockchain that is only open to some party or organization for certain purposes. In Private Blockchain, anyone wishing to enter must be invited or validated by the one who runs the blockchain. An example of a private blockchain is Hyperledger Fabric developed by the Linux Foundation [18].

3. Semi-private Blockchain

In semi-private blockchain, anyone may participate, but those who control the blockchain, such as verifying a transaction, are left to certain parties only [12].

According to [17] the comparison between public, private, and semi-private blockchain is as follows:

1. Consensus

Each node can be involved in the consensus process on public blockchain. While in private blockchain, the ones involved in the consensus process is the organization that created the blockchain. In semi-private blockchain, consensus can only be done by some parties.

2. Read Permission

All parties can view transactions in a public blockchain, whereas in private and semi-private blockchain, view access to transactions may be restricted and may not.

3. Efficiency

In public blockchain it takes a long time to disseminate transactions and blocks to joined nodes because of the large number of participants, thus the efficiency level of public blockchain is low. As for private and semi-private blockchain, it is more efficient because the validating parties are lesser, thus the efficiency of semi-private blockchain and private blockchain is high.

4. Immutability

Since all transactions are kept by a large number of parties and are open to everyone, it would be extremely hard to change a transaction in a public blockchain. Whereas in semi-private blockchain and private blockchain, because the amount of participation is limited, it is possible to change a transaction.

5. Centralized

The distinct difference between the three types of blockchain is that public blockchain is decentralized, while semi-private blockchain is between decentralize and centralize, and private blockchain has a fully centralized nature, this is because private blockchain are only controlled by the party that made it.

6. Consensus Process

In public blockchain, everyone can join the consensus process that is why it is permission-less, while in semi-private and private blockchain, the consensus process is done by some parties.

3. Disccusion

Blockchain Applications

In this section is presented some applications of blockchain technology.

Cryptocurrency

Blockchain was first used to record transactions for Cryptocurrency [6]. Cryptocurrency or so-called virtual currency, digital currency, or token, is a digital asset used as a medium of exchange. Cryptocurrency uses cryptography to secure and validate its transactions [19]. The first cryptocurrency that appeard in the public was Bitcoin [20][12]. The use of blockchain for cryptocurrency, by [20] is categorized as Blockchain 1.0.

Because cryptocurrency has not been considered legitimate by many governments [19], and no third party authorizes the occurrence of a transaction [15], therefore the process used to check and validate a transaction is through mining. Mining is a process of adding new blocks into blockchain [12]. Each block will contain transactions that have been validated through the mining process and performed by the miners [21][12]. Miners who successfully added a new block to the blockchain will be given some cryptocurrency units as compensation for the effort that they are doing [21]. The mining process requires a large amount of computer resources in order to make it more difficult for hackers to legitimate unauthorized transactions [14], and avoid double spending of the same cryptocurrency [12].

After the emergence of Bitcoin, various cryptocurrencies are emerging and marketed globally. Here are some cryptocurrencies available at the time of this writing:
1. Bitcoin [5]
2. Ethereum [22]
3. Ripple [23]
4. DigixDAO [24]
5. Litecoin [25]
6. Cardano [26]
7. NEO [27]
8. Stellar [28]
9. EOS [29]
10. IOTA [30]

Internet of Things

In the case of the Internet of Things (IoT), the use of Blockchain can make an important contribution in developing decentralized application which will manage an enormous amount of data, which will be running within billions of devices on earth, in order to keep the users privacy [31].

Blockchain is believed to be a promising technology that can be used in the payment system between connected devices [32]. In [32], the authors proposed an automatic payment system to be implemented by smart cable connected with smart socket, using Bitcoin. By using the blockchain technology, transaction process can be done cheaper, safer, and able to maintain privacy compared to payments done by using credit cards that currently exist.

Besides for payment between devices, according to [33], blockchain can provide security and privacy for smart vehicles. In [33], it is stated that the existing smart vehicles can provide various services that can benefit vehicle owner, transportation authorities, car manufacturers and other service providers. However, it actually makes smart vehicles vulnerable in terms of security and privacy. If the security and privacy is not being secured, hackers might attack the smart vehicle and endanger the safety of its passengers. Current security methods tend to be ineffective due to the following challenges: centralization, lack of privacy, and safety threats. Thus, the authors of [33], proposed a solution by designing a new security architecture based on blockchain, and was proven to be able to maintain the privacy of the users of the smart vehicle as well as improve the security of the smart vehicle.

Other research related to improving smart vehicle's safety is [34], where the authors propose a new reputation system based on blockchain to be used in smart vehicle's network. With the new reputation system, the smart vehicle can determine the credibility of a message received, based on the reputation value of the announcement system in the smart vehicle's network. Based on the results of trials conducted, it was proved that the reputation system based on blockchain plays an important role in assessing the credibility of the data so as to improve the security of the announcement system on the smart vehicle's network.

In the announcement system on the smart vehicle's network, it is necessary to provide the privacy of parties who send or share information on the network. To overcome this, [35] proposed a CreditCoin which is a new and secure network of announcement system based on blockchain, in which the sender's privacy can remain intact even though he/she sends information into an untrusted network.

Government

The government will always strive to provide the best service for its people. Various efforts have been used by the government to provide the best service, until finally emerged a new breakthrough that is e-government. Currently, e-government has been used in various countries to improve service for its people. However, the emergence of blockchain technology opened new opportunities to improve the e-government system. Many state governments are researching the use of blockchain to manage and provide public services [12]. Some of the countries that have focused and used blockchain are the UK [36], Georgia [37], India [38], Dubai [39], Netherlands [40], China [41], Sweden [42], Estonia [43] dan Honduras [44][45].

One of blockchain application in government is the e-voting system. Elections are done by almost every country in the world. The problems that exist in the current election process are

manipulation or error in entering election data by the committee, the security of election data, and the transparency of election data. Those problems makes [46] proposed a solution for securing election data using blockchain technology. In [46], the authors state that the result calculations of each voting place are hashed and chained to one another, making the recording of election results more secure. The electoral system that uses blockchain is also stated to reduce the cost spent by the country. One country that has used blockchain in its e-voting system is Estonia with its blockchain called the KSI blockchain [43].

Health Services

Blockchain offers many opportunities for use in the health sector [47]. Blockchain can be used in securing health data. Currently, the healthcare industry is faced with privacy and vulnerability problems contained in health data storage and in distributing patient's digital health data. The security of personal health data is essential to enhance interaction and collaboration in the healthcare industry.

One of the use of blockchain for health care is MedRec [48]. MedRec is a blockchain that uses public key cryptography. MedRec uses Ethereum's smart contract to make representations of current medical records. Any party incorporated into the network will receive a copy of the blockchain. Blockchain technology is used to control automation and tracking certain tasks, such as adding new data, or changing the right to view data. MedRec also proposed a mining model involving the health community incorporated into its network. MedRec is one of the solutions in storing and disseminating health data using blockchain.

Aside from MedRec, the Advanced Block-Chain approach to the electronic health system was proposed by the author of [49]. Advanced Block-Chain is designed to meet the demand in the field of health services. Through the ABC system, electronic health system can be done efficiently by eliminating intermediaries that exist today.

The author of [50] provide solution to protect the privacy of health data sent by electronic devices using permissioned blockchain. The author uses smartphone application to collect health data from multiple devices and synchronize data to cloud storage, to be shared with health care providers and health insurance companies. Data integrity is secured through proof of integrity and validation can be obtained from cloud storage which is then inserted into a blockchain designed using Hyperledger Fabric. In addition, in [51], the author propose attribute-based signature schemes using multiple authorities. This is used to ensure the validity of EHR (Electronic Health Record) data in blockchain.

Other Applications

Blockchain can be widely used in many fields, one of which is education. The author of [52] proposed EduCTX that could be used as a global blockchain based credit education platform. EduCTX able to create a trustworthy credit system and high-level education assessment globally. In [53], the authors propose peer to peer LFC (Leftover Foreign Currency) using blockchain technology in order to solve the problem of returning the rest of the foreign money into the circulation.

Blockchain can also play a role in smart city system. In smart city, optimizing lottery is one of the urgent needs to ensure fairness and transparency. Blockchain technology can be a solution to the problem of fairness and transparency faced by the lottery industry [54]. The author of [54] proposed the FairLotto system to address the problem. [55] stated that blockchain is suitable for supply chain. Blockchain can remove the needs of multiple intermediaries and digitized huge amount of paperwork in a supply chain network. Combined with internet of things, blockchain will save shipment data, delivery data, and location, to be used as a proof and can be seen by all participants in a supply chain network, such as Original Equipment Manufacturers (OEM), suppliers, third-party logistics providers, warehouses, and shippers.

Blockchain Challenges

Blockchain technology can provide promising renewal, however, blockchain technology is still considered a new technology and there are some challenges faced by blockchain. This section will discuss some of the challenges faced by blockchain technology.

Scalability

Blockchain has problem with scalability. Transactions stored in the blockchain will continue to increase each day, making the size of the blockchain bigger each day. Currently, Bitcoin's blockchain is only capable of processing one transaction per second, and theoretically the maximum transactions that Bitcoin's blockchain able to process is only seven transactions per second. The capability of processing transactions by the Bitcoin's blockchain does not meet the need to process millions of transactions [17]. That capability is very far compared to the transaction processing capabilities that can be done by VISA, with the capability of processing as many as 2000 transactions per second, and with a maximum capability of 10000 transactions per second. Other comparison is with Twitter, which is capable of processing 5000 transactions per second, and a maximum of 15000 transactions per second [20]. The solution to it is to increase the storage capacity of a block on Bitcoin's blockchain which currently only 1 MB [12]. However, according to [56], through their experiments, by creating larger block sizes, will create transmission delays between nodes, allowing multiple different participants to temporarily store blockchain with different versions, thus the blockchain cannot maintain it's integrity.

To solve the problem above, [57] proposed Bitcoin-NG (Bitcoin Next Generation). The main idea of Bitcoin-NG is to separate block in blockchain into two parts: The first is the key block that acts as a block that selects the leader and the second is the microblock that serves to store transactions. The new Bitcoi- NG protocol divides the time into several time periods. At each timeframe, the miners must do the hash to generate the key block. When a key block has been generated, the node becomes the leader that plays a role in generating the microblock. Bitcoin-NG also renews its longest chain strategy by creating microblocks that carry no weight at all [17]. In this way, blockchain is redesigned and blockchain scalability issues are resolved.

5.2. Privacy and Security

The privacy of a transaction is a very desirable feature in blockchain technology. However, blockchain is not able to guarantee transaction privacy because the value of all transactions and balances of any public key can be seen by the public, hampering its use in some industries that require privacy, such as finance and health [12][17]. To overcome this, [58] proposed a mixing service that can hide information between the sender and the receiver so that the relationship between the two can not be known by the public. But, according to [59], the relationship between the input and output addresses is not hidden from the party providing the mixing service. The party providing the mixing service has the ability to track the transaction of Bitcoin users. Therefore, [59] proposed a new way of mixing service using ring signature algorithm to provide anonymity of parties who transact through server mixing.

Security of the blockchain should be considered. According to [60], there are security issues exist in private and semi-private blockchain. This is due to the small number of participants who play a role in the operation of blockchain. Thus, some nodes can be hacked. Therefore, [60] proposed ChainGuard, which is an SDN module capable of detecting and preventing the flow of abnormal large packets on the network.

4. Conclusion

Blockhain, which acts as a digital ledger and securing transaction in a peer-to-peer network, has demonstrated its ability to change the current system. Several fields have implemented blockchain technology. Cryptocurrency or digital money transactions is the first area that implements blockchain. Other areas such as Internet of Things, government, electronic health system, education, smart city, and supply chain also implement blockchain technology because it provides solution to some problems that can not be overcome by the current centralized system. However, blockchain technology faces two major challenges in terms of scalability and in terms of privacy and security. There have been several attempts to overcome these two challenges,

such as proposing a new blockchain model called BitcoinNG, a way to maintain privacy with Ring Signature and ChainGuard to overcome blockchain's security challenge. For further research, there is a desire to investigate more about the applications of blockchain in a specific field, as well as the techniques used to address the challenges faced by blockchain technology in the future.

References

[1] A. Kurniawan, I. Riadi, and A. Luthfi, "Forensic analysis and prevent of cross site scripting in single victim attack using open web application security project (OWASP) framework," J. Theor. Appl. Inf. Technol., vol. 95, no. 6, pp. 1363–1371, 2017.

[2] S. Claessens, M. A. Kose, L. Laeven, and F. Valencia, "Understanding Financial Crises: Causes, Consequences, and Policy Responses," SSRN Electron. J., pp. 1–12, 2013.

[3] V. D'Apice and G. Ferri, Financial Instability, no. July. London: Palgrave Macmillan UK, 2010.

[4] V. Dhillon, D. Metcalf, and M. Hooper, Blockchain Enabled Applications: Understand the Blockchain Ecosystem and How to Make it Work for You. APress, 2017.

[5] S. Nakamoto, "Bitcoin: A Peer-to-Peer Electronic Cash System," 2008.

[6] M. Di Pierro, "What is the Blockchain," New York, vol. 19, no. 5, pp. 92–95, 2015.

[7] M. Gupta, Blockchain for Dummies, IBM Limited Edition. New Jersey: John Wiley & Sons, Inc., 2017.

[8] A. Booth, D. Papioannou, and A. Sutton, Systematic Approaches to a Successful Literature Review, no. September 2015. SAGE, 2012.

[9] L. A. Machi and B. T. McEvoy, The Literature Review: Six Steps to Success. SAGE Publications, 2016.

[10] A. Kurniawan, "Sejarah dan Analisis Deteksi dari Botnet Forensik : Sebuah Tinjauan Pustaka."

[11] T. Laurence, Blockchain: For Dummies. Hoboken: John Wiley & Sons, 2017.

[12] I. Bashir, Mastering Blockchain. Brimingham: Packt Publishing, 2017.

[13] W. Mougayar, The Business Blockchain. Hoboken: John Wiley & Sons, 2016.

[14] B. A. Tama, B. J. Kweka, Y. Park, and K. Rhee, "A Critical Review of Blockchain and It's Current Applications," in 2017 International Conference on Electrical Engineering and Computer Science (ICECOS), 2017, pp. 109–113.

[15] A. M. Antonopoulos, Mastering Bitcoin. Sebastopol: O'Reilly Media, 2017.

[16] N. Prusty, Building Blockchain Projects. Brimingham: Packt Publishing Ltd, 2017.

[17] Z. Zheng, S. Xie, H. Dai, X. Chen, and H. Wang, "An Overview of Blockchain Technology: Architecture, Consensus, and Future Trends," Proc. - 2017 IEEE 6th Int. Congr. Big Data, BigData Congr. 2017, pp. 557–564, 2017.

[18] "Hyperledger Architecture , Volume 1," vol. 1, p. 8, 2017.

[19] T. Laurence, "Blockchain For Dummies Cheat Sheet," in John Wiley & Sons, Inc., 2017, p. 202.

[20] M. Swan, Blockchain: Blueprint for A New Economy. O'Reilly Media, 2015.

[21] A. Judmayer, N. Stifter, K. Krombholz, and E. Weippl, Blocks and Chains: Introduction to Bitcoin, Cryptocurrencies, and Their Consensus Mechanisms, vol. 9, no. 1. Morgan & Claypool, 2017.

[22] G. Wood, "Ethereum: A Secure Decentralised Generalised Transaction Ledger," Ethereum Proj. Yellow Pap., pp. 1–32, 2014.

[23] D. Schwartz, N. Youngs, and A. Britto, "The Ripple Protocol Consensus Algorithm," Ripple Labs Inc White Pap., pp. 1–8, 2014.

[24] A. C. Eufemio, K. C. Chng, and S. Djie, "Digix ' s Whitepaper : The Gold Standard in Crypto Assets," 2016.

[25] C. Lee, "Litecoin." 2011.

[26] A. S. Approach and C. Hoskinson, "Cardano Whitepaper," pp. 1–44, 2017.

[27] "NEO White Paper." [Online]. Available: http://docs.neo.org/en-us/index.html.

[28] D. Mazières, "The Stellar Consensus Protocol: A Federated Model for Internet-level Consensus," pp. 1–45, 2015.

[29] I. Grigg, "EOS - An Introduction," no. ii, pp. 1–8, 2017.

[30] S. Popov, "The Tangle, IOTA Whitepaper," pp. 1–28, 2017.

[31] M. Conoscenti, A. Vetro, and J. C. De Martin, "Blockchain for the Internet of Things: A systematic literature review," 2016 IEEE/ACS 13th Int. Conf. Comput. Syst. Appl., pp. 1–

6, 2016.
[32] T. Lundqvist, A. De Blanche, and H. R. H. Andersson, “Thing-to-Thing Electricity Micro Payments Using Blockchain Technology,” 2017.
[33] A. Dorri, M. Steger, S. S. Kanhere, and R. Jurdak, “BlockChain: A Distributed Solution to Automotive Security and Privacy,” IEEE Commun. Mag., vol. 55, no. 12, pp. 119–125, 2017.
[34] Z. Yang, K. Zheng, K. Yang, and V. C. M. Leung, “A Blockchain-based Reputation System for Data Credibility Assessment in Vehicular Networks,” 2017.
[35] C. A. P. Blockchain-based et al., “Repository Announcement Network for Communications of Smart Vehicles CreditCoin : A Privacy-Preserving Blockchain- based Incentive Announcement Network for Communications of Smart Vehicles,” pp. 1–17, 2018.
[36] M. Walport, “Distributed Ledger Technology: Beyond Block Chain,” 2016.
[37] N. A. of P. R. Georgia, “State Project of Land Registration,” 2017.
[38] S. G. Binaifer Karanjia, Shankar Lakshman, “Blockchain Technology in India: Opportunities and Challenges,” Deloitte, 2017.
[39] A. Nordrum, “Govern by blockchain dubai wants one platform to rule them all, while Illinois will try anything,” IEEE Spectr., vol. 54, no. 10, pp. 54–55, 2017.
[40] “Blockchain Projects,” Dutch Government. [Online]. Available: https://www.blockchainpilots.nl/results.
[41] H. Hou, “The application of blockchain technology in E-government in China,” 2017 26th Int. Conf. Comput. Commun. Networks, ICCCN 2017, 2017.
[42] ChromaWay, “The Land Registry in the blockchain,” 2017.
[43] E-Estonia, “Estonian blockchain technology.” [Online]. Available: https://e-estonia.com/wp-content/uploads/faq-a4-v02-blockchain.pdf.
[44] C. Collindres, M. Regan, and G. P. Panting, “Using Blockchain to Secure Honduran Land Titles,” 2016.
[45] K. Schwab, The Fourth Industrial Revolution. 2016.
[46] R. Hanifatunnisa and B. Rahardjo, “Blockchain based e-voting recording system design,” 2017 11th Int. Conf. Telecommun. Syst. Serv. Appl., pp. 1–6, 2017.
[47] M. Mettler, “Blockchain technology in healthcare: The revolution starts here,” 2016 IEEE 18th Int. Conf. e-Health Networking, Appl. Serv. Heal. 2016, pp. 16–18, 2016.
[48] A. Azaria, A. Ekblaw, T. Vieira, and A. Lippman, “MedRec: Using blockchain for medical data access and permission management,” Proc. - 2016 2nd Int. Conf. Open Big Data, OBD 2016, pp. 25–30, 2016.
[49] W. Liu, S. S. Zhu, T. Mundie, and U. Krieger, “Advanced Block-Chain Architecture for e-Health Systems,” no. Etpha, pp. 37–42, 2017.
[50] X. Liang, J. Zhao, S. Shetty, J. Liu, and D. Li, “Integrating Blockchain for Data Sharing and Collaboration in Mobile Healthcare Applications,” no. October, 2017.
[51] R. Guo, H. Shi, Q. Zhao, and D. Zheng, “Secure Attribute-Based Signature Scheme with Multiple Authorities for Blockchain in Electronic Health Records Systems,” IEEE Access, vol. 3536, no. c, pp. 1–1, 2018.
[52] M. Turkanović, M. Hölbl, K. Košič, M. Heričko, and A. Kamišalić, “EduCTX: A blockchain-based higher education credit platform,” vol. X, no. November 2017, pp. 1–15, 2017.
[53] R. Bhattacharya and M. White, “A Blockchain based Peer-to-Peer Framework for Exchanging Leftover Foreign Currency,” no. July, pp. 1431–1435, 2017.
[54] D.-Y. Liao and X. Wang, “Design of a Blockchain-Based Lottery System for Smart Cities Applications,” 2017 IEEE 3rd Int. Conf. Collab. Internet Comput., pp. 275–282, 2017.
[55] P. A. Laplante and B. Amaba, “Blockchain and the Internet of Things in the Industrial Sector,” It Prof., vol. 20, no. 3, pp. 15–18, 2018.
[56] J. Göbel and A. E. Krzesinski, “Increased block size and Bitcoin blockchain dynamics,” Proc. 2017 27th Int. Telecommun. Networks Appl. Conf., pp. 1–6, 2017.
[57] I. Eyal, A. E. Gencer, E. G. Sirer, and R. van Renesse, “Bitcoin-NG: A Scalable Blockchain Protocol,” 2015.
[58] M. Möser, “Anonymity of Bitcoin transactions. An analysis of mixing services,” Münster Bitcoin Conf. 17-18 July 2013, pp. 17–18, 2013.
[59] Y. Liu, R. Li, X. Liu, J. Wang, C. Tang, and H. Kang, “Enhancing Anonymity of Bitcoin Based on Ring Signature Algorithm,” 2017 13th Int. Conf. Comput. Intell. Secur., pp.

317–321, 2017.
[60] M. Steichen, S. Hommes, and R. State, “ChainGuard -A Firewall for Blockchain Applications using SDN with OpenFlow,” 1855.